deform to spread further. The later stages of spreading, however, are also known to involve active mechanisms such as actin polymerization and myosin contractions [4–6], so the full process is too complex to be described by a single theory.

In earlier studies of the dynamics and metabolic requirements of cell spreading, inhibitors of energy metabolism were found to have no affect on early cell attachment and deformation [7–9]. These studies further showed that cells are truly adherent after early spreading because they resist detachment by fluid shear forces [9]. The quantitative arguments of Cuvelier *et al.* [2] explain these results, and require that the actin cortex relax as a viscous liquid during early cell spreading. Indeed, the group only saw a deviation from the $\frac{1}{2}$ power law when they used cytochalasin to disrupt the actin network.

The ability of an adherent cell to spread has important consequences. Studies dating back to the pioneers of cell culture established that substrate contact area can determine whether or not a cell proliferates [10], becomes quiescent [11,12] or dies [13]. While it is likely that active mechanisms provide the feedback that controls these responses to spreading, the results of Cuvelier *et al.* [2] are important to explain how a cell gets a 'foothold' on a surface in the first place. A universal model for early adhesion may have application to understanding the formation of stable contacts between blood cells and endothelium *in vivo* [14], and may aid in the rational design of tissue engineering surfaces in which cells are seeded in spatially defined patterns [15]. The results suggest that cells of different types can adhere to the same surface so long as the surface provides for non-specific associations between cell and substrate.

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Brain Stimulation: Feeling the Buzz

A recent study demonstrates that artificially generated patterns of brain activity are surprisingly easy to sense. Brain areas that differ substantially in their functional specialization are remarkably similar in their ability to support this awareness.

John B. Reppas and William T. Newsome

Few demonstrations of the link between brain and mind are as compelling as experiments in which behaviors are evoked or modified by perturbing brain activity. More than a hundred years have passed since Fritsch and Hitzig [1,2] pioneered what remains one of the most effective ways to do this: by passing an electrical current into the brain. By stimulating the motor cortex and eliciting body movements, they showed for the first time that artificially activating different parts of the brain could elicit reproducibly different behaviors. In the modern era, brain stimulation has been used to probe the organization of a wide range of higher brain functions, including perception [3–6], attention [7] and learning [8]. As brain stimulation has entered this cognitive realm, its effects have been demonstrated by inference, not by direct observation. Drawing the correct conclusion about how and where brain stimulation interacts with cognitive processing depends more than ever on the design and control of experiments, and even these may not fully constrain the possible interpretations [7,9,10].

Life might be easier if we could know what subjects are feeling during brain stimulation, in addition to simply observing what they are doing. For human subjects, who can put those feelings into words, this is relatively easy. The

neurosurgeon Wilder Penfield [11] famously did just this, when he asked patients to describe what brain stimulation felt like. While humans are indeed able to give reproducible accounts of what brain stimulation feels like, it is rare to study human behavior in this setting (even though there are numerous therapeutic applications of brain stimulation [12]). Brain stimulation is instead most commonly used to study various animal models of human cognition, where it is called 'microstimulation'. These model systems offer the advantage of well-understood neural circuitry, but preclude the opportunity for verbal feedback about the subjective effects of microstimulation on that circuitry.

A new study by Murphey and Maunsell [13], reported in this issue of *Current Biology*, suggests that we may not have to wait until animals can talk in order to learn something about what brain stimulation in a non-human model might feel like. This study asks of rhesus monkeys a question similar to one Penfield asked of his human subjects: can they sense directly when the stimulating current is being applied? Unlike Penfield, however, the authors are deliberately indifferent to the so-called qualia of this artificial experience. Instead, they focus on how much current must be passed to enable the monkey to report the moment of stimulation accurately. They tackled this problem by assuming that electrical stimulation generates a neural signature that can be processed and detected as if it had been generated by an external visual stimulus (Figure 1).

The first big surprise is that a threshold for detecting brain stimulation can be measured at all. There is nothing remotely natural about the neural activity that a stimulating electrode elicits, and it is certainly unlikely to resemble the stimulus-evoked responses that the monkey detects routinely. Despite this, Murphey and Maunsell [13] were able to obtain a principled and monotonic relationship between current intensity and detection performance in every visual area that they tested. Indeed, their

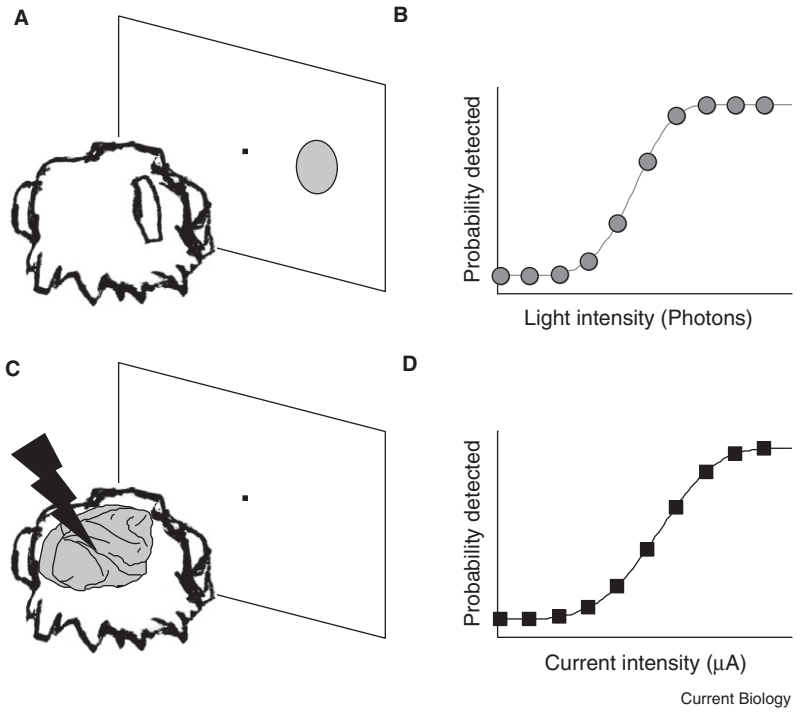

Figure 1. Experimental approach used by Murphey and Maunsell [13].

(A) Monkeys were first trained to detect a peripheral visual stimulus (grey circle). (B) The psychometric curve relating a property of that stimulus (light intensity, for example) to the monkey's ability to detect it. (C) Once the monkeys were trained on the detection task, microstimulation was substituted for the visual stimulus (black lightning bolt). (D) The psychometric curve relating the intensity of brain stimulation to the probability that the monkey detected it.

stimulus–response functions look indistinguishable from the psychometric curve that, under more typical circumstances, defines a subject's threshold for detecting a stimulus quality such as light intensity [14]. Whether data like these can only be obtained from the visual (or other sensory) cortex — whose normal role, after all is to detect and categorize sensory inputs — or whether it is a generic property of the cerebral cortex remains an open and interesting question.

Practitioners of microstimulation may be surprised to learn just how low these thresholds were. The amounts of current that were reliably detected in this study fell well within the range that has been used to bias perceptual judgments and manipulate attention in many of the same brain areas [15]. A tacit assumption of those previous studies is that the animal is not aware of the microstimulation. Indeed, most experiments go to great lengths to prevent the monkey from knowing when the electrical stimulation is delivered, to eliminate any possibility that the experimenter is unwittingly cuing the animal to behave differently. Murphey and Maunsell's [13] results raise the possibility that this assumption may no longer be correct in all situations. One consideration, however, that may slow any rush to judgment is that the monkeys in these experiments were trained explicitly to expect and to detect brain stimulation. In more typical studies, animals are engaged in behaviors where success or failure is unrelated to detecting microstimulation per se. Absent a dedicated effort to detect it, microstimulation may be less discernable than these results suggest.

Notwithstanding this concern, it is clear that — under these particular conditions — microstimulation can be detected with relative ease. What might account for this? A reasonable guess would be that the site of stimulation is a major determinant: some brain areas, either by virtue of

the way they represent visual information [16] or their particular patterns of connectivity [17], may be better than others in allowing artificial activity to seep into consciousness. Murphey and Maunsell [13] addressed this possibility by measuring thresholds from five different areas in the visual cortex. These ranged from the primary visual cortex, which is the first cortical way station for information arriving from the retina, to inferotemporal cortex, thought to be the highest stage of processing relevant to object recognition. As a group, these areas span the breadth of almost every measure one might consider relevant to this question, predicting a broad range of threshold sensitivities. In fact, just the opposite was observed: threshold current increased by only a factor of two as increasingly higher visual areas were stimulated. If the threshold current is treated as a stand-in for the number of neurons that must be stimulated for the animal to be aware of the microstimulation [18], these results argue strongly that the visual cortex is surprisingly egalitarian in the way it accords access to awareness.

Of course, we don't know what this awareness might have looked or felt like. While Murphey and Maunsell's [13] results do not hint at the subjective dimensions of the effect, future experiments might. If microstimulation effectively reproduces normal visual experience, as might be expected in the early visual areas, it should be possible to study the visual qualities of the percept with psychophysical approaches that have been successfully used to understand illusory perception. For example, stimulation of directionally selective neurons in visual area MT (or V5) might generate a perception of motion, whose direction could be estimated objectively by a nulling procedure [3,19]. Especially as higher-tier brain areas are stimulated, however, the possibility exists that the evoked percept is wholly unlike anything that the animal has ever experienced [20], in which case these approaches will fail. This would represent a fundamental limit on what the scientific (third-person) approach is able to tell us about a subjective (first-person) experience. Maybe we will need to teach monkeys how to talk after all.

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Dispersal Ecology: Where Have All the Seeds Gone?

How effective are different animals at dispersing seeds? A new study has traced seeds sampled in faeces to their mother of origin and concluded that carnivorous mammals can be better dispersers than birds.

John R. Pannell

The ecological and evolutionary success of any species ultimately depends on its ability to disperse and spread its genes. Most animals do it by moving around, but dispersal poses a serious challenge to sessile plants. Of course, plants have risen to the challenge by co-opting vectors such as wind or animals to carry their seeds and pollen. The mechanics of how they do it has long fascinated biologists, but describing the precise paths taken has been exceedingly difficult, not least because it is the rare events of successful long-distance dispersal that are both the most elusive to track down and the most biologically far-reaching [1,2]. Most seeds and pollen are dispersed close to their parent plant [3], but a few of them reach long distances, and these allow the spread of adaptations to distant populations,